manner, the added cost may be justified by all the attendant benefits over traditional open surgery.

Robotic lobectomy is a feasible, safe, and oncologically sound surgical treatment for early-stage lung cancer. The technique is reproducible across multiple centers and yields results consistent with the best seen with conventional VATS. It should not be considered experimental, but an accepted minimally invasive thoracic surgical technique. Future evaluation of differences between robotic versus VATS versus thoracotomy approaches to thoracic diseases is warranted.

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Discussion

Dr Thomas A. D'Amico *(Durham, NC).* Robotics has been used in numerous surgical procedures, but, with few exceptions, this technologic advance has not translated into improved outcomes. Many robotic applications have been unveiled as the manifestation of a tool—sometimes a marketing tool—in search of an application. The principal advantages of robotic assistance in surgery are the greater degree of instrumental articulation and motion scaling. However, despite these recognized technical advantages, the demonstration of superior outcomes has been disappointing. As well, several disadvantages of the robotic system have been proven, including the lack of tactile feedback, personnel commitment, cost of the robot and its instruments, and the length of the procedures. In addition, the instrumentation that is currently available for use robotically is still limited.

The multi-institutional retrospective review by Park and his colleagues represents the largest robotic lobectomy series to date; more than 325 consecutive patients underwent robotic lobectomy for early-stage disease at the 3 institutions. The conversion rate was, admirably, relatively low, only 8%, with reasonable morbidity, consistent with thoracoscopic lobectomy series in the literature. The length of stay was longer, perhaps with the inclusion of patients in Europe. Finally, stage-specific survival was excellent, also consistent with both open and thoracoscopic experiences, including patients with stage IIIA disease. Thus, the authors have demonstrated that robotic lobectomy for early-stage disease is effective, feasible, oncologically sound, and comparable, but not superior, to thoracoscopic lobectomy.

Less clear is the compared effectiveness of the robot vis-a-vis thoracoscopic lobectomy. Although thoracoscopic lobectomy has been demonstrated to be superior to open lobectomy in terms of outcomes and costs, analyses of the costs relating to robotic lobectomy suggest that the procedure is approximately $2000 more expensive than open and $4000 more expensive than VATS. In light of these issues, I have 3 questions, and I will ask them 1 at a time.

How should the cost of robotic lobectomy be considered in the evaluation of its effectiveness? Unlike some technologies in which cost has decreased over the evolution of the technology, the opposite seems to be happening with robotics; costs continue to increase, both fixed and variable. Although the promise that this technology as the future of all surgery has been adamantly put forward by others, I believe that a more logical response is required to adequately assess the effectiveness of robotic lobectomy.

Dr Park. Thank you for that analysis and question.

Cost is an extremely important feature, and you are right, robotics is a technology. I think it is critical to compare robotics (a minimally invasive modality) to thoracotomy, which is still the standard approach throughout the world. You stated that studies have shown that robotics is more expensive than thoracotomy, but I think that does remain to be seen and proven. We are going to be presenting a paper at the meeting of The International Society for Minimally Invasive Cardiothoracic Surgery (ISMICS) next month that compares costs associated with VATS versus robotic versus thoracotomy, which I believe will begin to address this. I

think a critical issue is this: does robotics allowing us to transition from thoracotomy to minimally invasive approaches to early-stage lung cancer in the appropriate patients? Therefore, any cost analysis has to take that into account. If you are able to transition more surgeons into doing oncologically sound and safe procedures minimally invasively through the use of robotic technology, then perhaps those costs are justified. However, all things being considered, I think if you were to compare VATS nonrobotic and robotic in the most excellent hands, then yes, there's no question that robotics is more expensive. Whether that cost is justified depends on whether we could have most of our thoracic surgeons or people who do thoracic surgery do it by VATS.

Dr D'Amico. The issue of the transition brings up my second question. Inasmuch as thoracic surgeons, both in and out of training, are not adequately exposed to robotics, how do you recommend that surgeons take on this new technology to assure competency?

Dr Park. That question is in parallel to questions about advanced minimally invasive surgery in general. At most of our excellent training programs, the trainees are getting more and more exposed to advanced minimally invasive surgery, but that still leaves a whole population of surgeons who only know how to do thoracotomies, and they are faced with the same challenge of having to figure out how to do advanced VATS surgery, let alone robotic surgery. I think it is incumbent on major organizations, like The American Association for Thoracic Surgery and The Society of Thoracic Surgeons, to come up with guidelines for defining the appropriate use of such technologies and the minimum credentialing so that surgeons can get trained and be deemed to be qualified in these procedures. We need the organizations to come forth and define what the procedures are, to define how people can get trained in those procedures, and then to allow hospitals throughout the country and the world to determine how they can credential their surgeons and deem that they are qualified to do these procedures.

Dr D'Amico. I do not have an answer to my own question, but surgical associations have never done that for any other procedure, so I do not see The American Association for Thoracic Surgery or The Society of Thoracic Surgeons or the Board coming up and saying: This is how you need to do it. It is going to have to come from somewhere, but I would not necessarily expect that the associations would do it.

Finally, please comment on the impact of new robotic technology that is on the frontier: single-port entry, new energy sources, in-line staplers, infrared optics for sentinel node technology, simulation programs, and others. How do you think these new advances will translate into improved effectiveness for lobectomy?

Dr Park. I think simulation, as you mentioned, is one of the critical new technologies that is going to allow trainees or anybody who is established who wants to learn this technology and advanced minimally invasive techniques to do this in a more safe environment, to get practice without putting patients at harm. There is going to be stapling technology to allow direct control of the stapler. I think using the 3-dimensional optics is going to be a huge benefit, because even with some of the newer-technology staplers, most of us still feel some trepidation passing the staplers behind the hilar structures, and I think that is only going to help. Certainly, other instrumentation to help with retraction, exposure, and suctioning will all help. However, as you alluded to before, they are going to potentially result in increased costs. I think we have to evaluate these critically and decide which are necessary, and that will make these procedures safer and more feasible.

Dr Scott J. Swanson *(Boston, Mass).* What I would like to do now is just put on your hat of senior lung cancer surgeon. With the lung cancer screening trial coming and the fact that VATS lobectomies have gone from about 10% to 30%, how would you use this technology across the country? Do you think it is realistic that all hospitals should have a robot and everyone should learn it? Should there be centers where people go for robotic surgery? How realistically should we get more minimally invasive operations to our patients?

Dr Park. We have to remember that the 30% number is from The Society of Thoracic Surgeons voluntary database. There are other nonvoluntary databases that show that some rates of VATS lobectomy are as low as 6%. I am not sure that we are seeing an explosion of VATS lobectomy as a technique. I would love to think that that is true.

Your question is very similar to Dr D'Amico's.

As with any other technology, we need to identify centers of excellence and concentrate on trying to bring people to see what is going on in those centers, to organize training courses so that people can gain exposure to minimally invasive techniques and decide for themselves whether they are reasonable options and whether they do fit with their armamentarium. With increasing early-stage disease, increasing minimally invasive approaches is warranted and necessary, not only for the benefit of the hospital but for the benefit of the health care system in general in terms of allowing patients to recover quicker, getting them out of the hospital, and getting them back to their preoperative state.

Dr K. Adam Lee *(Cherry Hill, NJ).* In your data did you see any difference between a 3-arm approach and a 4-arm approach? Looking forward, do you see the robotic assisted technique transitioning an open thoracotomy surgeon to become more involved in minimally invasive surgery? Do you see some of those positive results of the robotics procedure helping to reach that goal?

Dr Park. There was no real difference between 3-arm and 4-arm techniques. Again, 2 of the centers had a 4-arm technique and 1 had a 3-arm technique, but basically there was just 1 additional incision. All of the unified themes of non–rib-spreading and using videoscopic guidance were the same. There was no real difference clinically.

It is really hard to know whether robotics can help traditional thoracotomy surgeons transition to minimally invasive. I think we have to study that, if it is feasible, prospectively. I know, again, that VATS lobectomy and the excellent results that are published are being done so by essentially a core group of outstanding practitioners at great centers. The question is not whether robotics is the answer as opposed to VATS; the question is how we can appropriately use technology to increase the percentage of minimally invasive procedures that are done appropriately.

Dr Todd L. Demmy *(Buffalo, NY).* Another surgeon who performed many robotic lobectomies commented that a large tumor in the upper lobe is a hassle, and this gets to the issue with the robot having just 1 implementing arm per port. With thoracoscopy, you can use multiple retractors from a single port and handle that large tumor. In your study, did you notice any effect of big tumors in the upper lobe? You had a 10-cm specimen. Was that in the lower lobe?

Dr Park. All of the techniques had a utility incision and most of the assistants were able to retract through the utility incision. I am aware of no increased difficulty with larger tumors in these robotic series.

Dr Joachim Schirren *(Wiesbaden, Germany).* The patients in stage IA and 1B are nearly cured, but in stage II, you have results you can reach in open surgery in stage III. Therefore, my question is how many systemic relapses did you have and how many local relapses did you find in this stage?

Dr Park. Only 9 of the 32 patients had local-only relapse, and the majority of the 32 patients had either local plus distant or distant relapse. It was really systemic recurrence.